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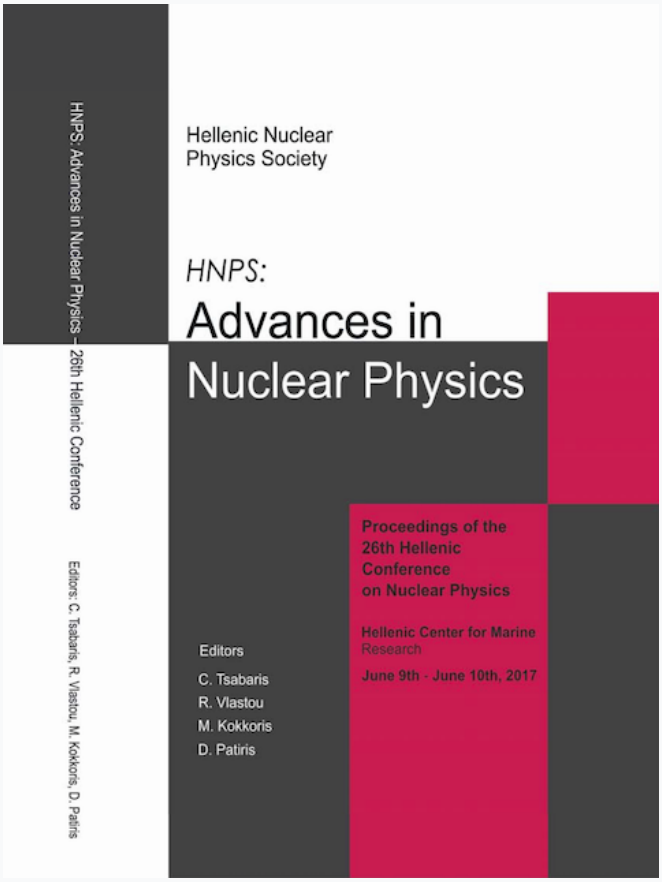

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The Greek lessons of the Chernobyl nuclear accident

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Abstract The specifics of the environmental radioactive contamination in Greece after the Chernobyl accident is analyzed. The principal radiological pathways of the radioactive pollutants to the human organism are discussed, together with the doses from different food categories, the evolution of dose burden in time and the effect of regional smoothing on the dose differences. The main lessons from this radiological crisis are related to the lack of early information, the international exchange of data, the role of the metrology trust, the optimization of the measurement methodology and measured objects. Problems of the information and misinformation of the population are discussed as well.

Marine Radioactivity (^{137}Cs) in the Eastern Mediterranean: Sources, pathways and time evolution

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Abstract The waters of our oceans contain many different radionuclides. Some of them are natural byproducts of planetary and celestial processes, but some are the results of technological progress for military, industrial and medicine uses called artificial radionuclides. Cs-137 is one of those artificial radionuclides presenting the greatest radiological concern (^{137}Cs, ^{134}Cs, ^{90}S, the isotopes of Pu and Am), the main source of which is the global fallout of the nuclear weapon testing programs, whereas the second largest source of it is related to the accident of the nuclear power plant at Chernobyl. Besides the global sources, in the Eastern Mediterranean there are areas of radiological consideration as are the North Aegean Sea where the Black Sea impact from the reactor operations in Ukraine has been detected since 1982 and the South Aegean Sea (Souda, Crete) as a potential area of concern due to nuclear powered vessels that visit the area. The dispersion of ^{137}Cs in the Eastern Mediterranean is governed by the environmental parameters, mainly the sea currents and also its solubility. Thus, the ecological half life which is estimated on the basis of the ecosystem futures and the physical half life rules the dispersion of the radioactive pollutant, while its distribution to the environmental components is dependent not only on the abiotic conditions but also on the biological ones such as bioaccumulation/bioconcentration, bioavailability, the biota taxon, the life cycle of the organisms, the synergism with other pollutants. In the highlight of this consideration, the evolution of the radioactive pollution due to ^{137}Cs in the Eastern Mediterranean is presented in a period covering more than 30 years.

Keywords Radioactivity in the Eastern Mediterranean, ^{137}Cs in the marine environment, Radioactivity impact assessment

Response of the Greek early warning system Reuter-Stokes ionization chambers to terrestrial and cosmic radiation evaluated in comparison with spectroscopic data and time series analysis*

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Abstract The Telemetric Early Warning System Network of the Greek Atomic Energy Commission consists of two sub-networks: a network of 24 Reuter-Stokes high pressure ionization chambers for gamma dose rate measurements covering all Greece, and a network of three air radioactivity monitoring stations. In the present work, the response of the Reuter-Stokes high pressure ionization chambers (HPIC) to terrestrial and cosmic radiation was evaluated in comparison with spectroscopic data and time series analysis. The spectroscopic data were obtained by 87 *in situ* gamma spectrometry measurements with portable Germanium detectors (HPGe), near the Reuter-Stokes detectors, in six of the 24 locations of the Greek early warning system network during the years 2014-2016 and 10 *in situ* gamma spectrometry measurements in ten locations of the Greek early warning system network during the year 2001. HPGe detectors are sensible only to terrestrial gamma radiation. On the contrary Reuter-Stokes detectors are sensible also to cosmic radiation. Therefore, the comparison between the dose rates measured by the two instruments can reveal information concerning the response of the Reuter-Stokes detectors to terrestrial and cosmic radiation. Time series analysis of the mean monthly dose rate in air (measured by the Reuter-Stokes detector in Thessaloniki from 2001-2016) was performed with advanced statistical methods (Fast Fourier Analysis and Zhao Atlas Marks Transform). Fourier analysis reveals several periodicities (periodogram). The periodogram of the dose rate values was compared to the periodogram of the dose rate values measured for the same period (2001-2016) and in the same location with a NaI (Tl) detector which in principle is not sensible to cosmic radiation. The obtained results are presented and discussed.

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Possibilities for basic and applied research in X-ray spectrometry using the IAEA multi-technique instrument operated at the XRF beamline of Elettra Sincrotrone Trieste

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Abstract The International Atomic Energy Agency (IAEA) operates jointly with the Elettra Sincrotrone Trieste (EST) a multi-technique X-ray spectrometry end-station [1-3] at the X-ray Fluorescence (XRF) bending magnet beamline [4]. The facility is accessible to end-users since the beginning of 2015 through the established peer-review process of EST. Through this collaboration the IAEA promotes and supports synchrotron based experiments and training activities by research groups from IAEA Member States with limited previous experience and resources to access synchrotron radiation facilities. The research areas of interest include characterization of nano-structured materials (solar cells, Li-ion batteries, etc.), characterization and speciation of environmental samples [5, 6] (airborne particulate matter, water samples, suspensions, coal fly ash), study of essential or toxic elements in plants to develop/improve biofortification, phytoremediation and phytomining techniques, speciation of trace elements in human tissues for cancer studies, advanced materials for preventive conservation, study of ancient technologies of manufacture, and systematic measurement and re-evaluation of X-ray fundamental parameters [7]. The EST-IAEA X-ray spectrometry facility offers advanced analytical features available to limited number of synchrotron radiation facilities worldwide, namely to perform XRF measurements at different excitation or detection geometries combined with X-ray absorption or X-ray reflectometry (XRR) measurements, thus supporting a comprehensive characterization of different kind of materials. Results obtained from interdisciplinary applications are reported and discussed highlighting the analytical capabilities of this new X-ray spectrometry facility.

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Submarine pockmarks area localization using in-situ radio-tracing technique in Eckernförde bay, Germany*

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Abstract Eckernförde Bay is a narrow bay ("Förde" in German or "Fjord" in Danish) of 16 km length and 2–6 km wide situated on the east coast of Schleswig-Holstein (northern Germany) in the south-western Baltic Sea. For the scientific community, noteworthy aspects of the bay concerns the extensive methane production in sediment and the presence of pockmarks areas. Pockmarks are morphological seafloor's depressions (craters) of atypical shapes with depth of 1-2 m which in numbers form pockmarks areas. The main pockmarks areas are located in the centre of the bay and along the south bank. Interstitial fluids of the sediments in the pockmarks contain very low or undetectable methane concentrations so, methane production does not involve in creation neither in maintenance of the pockmarks. The pockmarks of the bay are submarine springs of non-continuous but rather episodic groundwater emanation. Groundwater is rich in natural radionuclides and especially in radon gas. The aim of the present work was to assess the possibility of pockmarks localization by radio-tracing method based on spatial variations of radon progeny (bismuth ^{214}Bi) and natural radioisotope of potassium (^{40}K) as well as, to provide an estimation of radon activity concentration in the emanating groundwater flows.

*This work was implemented in the framework of the EU funded Horizon 2020 COST Action ES1301 "**COST – FLOWS**: Impact of Fluid circulation in old oceanic Lithosphere on the seismicity of transform-type plate boundaries: new solutions for early seismic monitoring of major European Seismogenic zones".

Exploring Lepton-Flavour Violating Processes Through Neutrino Detection

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Abstract Neutral-current (NC) and charged-current (CC) neutrino-matter processes within and beyond the Standard Model (SM) are explored from low energies up to the energy range of quasi-elastic scattering [1-4]. In particular, the study focuses on the non-standard neutrino scattering off nucleons $N = n, p$ described by the exotic reactions $\nu_a + N \rightarrow \nu_\beta + N$, with $a \neq \beta = e, \mu, \tau$, that provide corrections to the dominant SM processes [5]. In this context, it is shown that the required exotic nucleon form factors may have significant impact to the relevant cross sections. Besides cross sections, the event rate is expected to be rather sensitive to the magnitude of the lepton-flavour violating parameters resulting to an excess of events. The overlap of non-standard interactions and strange quark contributions, in the region of few GeV neutrino energies, is also examined. The formalism is applied for the case of the relevant neutrino-nucleon scattering experiments (LSND, MiniBooNE, etc.) [6] and motivates that such facilities have high potential to probe NSI. We furthermore investigate the impact of a fourth sterile neutrino at reactor and Spallation Neutron Source neutrino detectors [7]. Specifically, we explore the discovery potential of the TEXONO [8] and COHERENT [9] experiments to sub-leading sterile neutrino effects through the measurement of the coherent elastic neutrino-nucleus scattering event rate. Our dedicated χ^2-sensitivity analysis employs realistic nuclear structure calculations adequate for high purity sub-keV threshold detectors.

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Lead and Uranium isotopes in Sahara Dust Aerosol observed in Athens by Alpha spectrometry

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Abstract An atmospheric sampling program by means of High Volume sampler is established at Demokritos Atmospheric Aerosol and Radioactivity station since March 2011. The station is located at the North East part of the Greater Athens Metropolitan Area and at an altitude of 270 m.a.s.l. and is a member of the WMO Global Atmosphere Watch and Ro5 monitoring programmes. Measurements were conducted using a six-stage high volume cascade impactor (nominal 50% cutoff sizes: 10.1, 4.2, 2.1, 1.4, 0.73, 0.41, 0.05 μm). Concentrations of radioisotopes were measured after weekly sampling. 238U and 234U were determined by means of a-spectrometry. 210Pb has been measured via 210Po also using a-spectrometry. All three radionuclides have been radiochemically separated with the separation procedure based on three steps: sample pre-treatment, ion-exchange and source preparation. For the calculation of the radionuclide concentrations and the chemical yield of each measurement, the filter samples were spiked by a known aliquot of yield tracers, with 232U for the uranium isotope determination and 209Po for the determination of 210Po. Back-trajectory analysis was conducted for the study of the long-range transport of air masses to Athens in this period by means of the HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model (Draxler and Rolph, 2012). In order to have a clear picture of the density of the Sahara – dust phenomenon, the trajectory results were combined with daily data by the Skiron model (reanalysis data) during the studied period. These data are hourly time series of estimated dust mass concentration at various heights (Kalos et al., 2006). The activity concentrations of the three analyzed isotopes in coarse and fine aerosol samples during the samples studied were highly variable and close to background. Especially, when air masses arrived in Athens from North and East Europe, activities of these isotopes are in most cases below detection limit. On the other hand, results obtained during the Sahara dust events follow a rather different pattern with higher activities observed and proportional to the dust load.

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Surface sediment geochemistry of the North Aegean Sea: heavy metal hot-spots

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Abstract The north Aegean Sea (NAS) lies in the eastern sector of the Mediterranean basin and is characterized by alternating deep basins (>1500 m water depth) and shoals as well as a complex coastline configuration. Freshwater and sediment is supplied by a number of major rivers, i.e. Pinios, Aliakmon, Axios, Loudias, Gallikos, Strymon, Nestos, and Evros, which drain the Greek mainland, FYROM, Bulgaria, and Turkey. Moreover, the area is substantially influenced by the inflow of brackish waters of Black Sea origin, entering the north Aegean Sea through the Dardanelles straits. The sedimentology and geochemistry of Thermaikos gulf and Sporades basin have been studied in past years [1], whereas a comprehensive study of the entire NAS is still missing. Taking into advantage the results of an extensive nationally-funded project, we present for the first time the regional geochemistry of the NAS, focusing on the distribution of selected heavy metals and the identification of environmental hot-spots. A set of 417 bulk surface sediment were analyzed by X-ray Fluorescence at the laboratories of the Hellenic Centre for Marine Research, and several major and minor elements were determined. Moreover, preindustrial core sediments were analyzed with the same methods to establish the background levels of selected heavy metals and the subsequent determination of enrichment factors (EF), in order to assess potentially contaminated areas and their degree of deviation from normal levels. The Ierissos gulf is the most contaminated site as far as it concerns Pb, As, and Zn, associated both with mine tailings and natural weathering of sulfide ores. The bay and gulf of Thessaloniki are also contaminated in Pb, Zn, and Cu, attributed to port and industrial activities, as well as the release of domestic effluents. Finally, all river deltaic deposits show variable degree of elevated heavy metal contents and relatively high EFs, thus highlighting the impact of heavy-metal enrichment originating in the rivers' catchment areas and the human activities taking place in the mainland.

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The use of natural and anthropogenic radionuclides in calculating the recent sedimentation rates in the marine environment

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Abstract Several radionuclides can be used as tracers of various marine processes (i.e. sedimentation, accumulation, erosion). Recent sediment accumulation can be assessed using ^{210}Pb (half-life 22.3 yr) and ^{137}Cs (half-life 30.7 yr). The natural radionuclide ^{210}Pb is continuously introduced into the marine environment adsorbed on atmospheric particles, after decay of ^{222}Rn exhaled from the continental crust. The radioactive decay of dissolved ^{226}Ra in the water column is also a source of ^{210}Pb. Because of its reactivity, it rapidly becomes associated with suspended matter and, therefore, subject to sedimentation. The down-core activity of ^{210}Pb is determined through its a-emitting granddaughter ^{210}Po, assuming secular equilibrium with ^{210}Pb. Cesium-137 is a bomb-derived radionuclide, first introduced into the atmosphere in 1954 with the onset of weapon testing. An important source of ^{137}Cs in the marine environment is the Chernobyl accident. Peaks occurring in the vertical distribution of ^{137}Cs activity along the sediment core correspond to 1963 (the year of maximum fallout from atmospheric weapon testing) and 1986 (related to the Chernobyl accident). A characteristic ^{210}Pb profile consists of an upper sediment layer of homogeneous activity (i.e., the surface mixed layer) lying above a layer of decreasing activity, which eventually reaches levels supported by ^{226}Ra at depth in the seabed (background levels). However, in areas with episodic and rapid depositional events layers of low activity are observed in the profile, which provide a record of past depositional effects. In these types of profiles, the sediment accumulation rate can be estimated fitting the experimental data (logarithmic values) along with depth. The ^{210}Pb activity is measured on 0.1 g of dried sediment samples via the ^{210}Po alpha emitter assuming secular equilibrium with ^{210}Pb. The dried samples are attacked with HNO_3, HF and HCl. The isotopes are deposited on silver discs after reduction of Fe^{3+} to Fe^{2+} with ascorbic acid. The discs are then placed between ZnS (Ag) phosphor discs and both sides are measured with a total alpha counter (ORTEC EG&G). The background (supported) ^{210}Pb activity is calculated from the averaged activities of the radon progeny gamma ray emitters (^{214}Pb at 295.2 keV, 351 keV and ^{214}Bi at 609 keV). The excess (unsupported) ^{210}Pb-specific activity is calculated by subtracting the supported from the total ^{210}Pb-specific activity. Data quality control is performed using standards samples (IAEA-414). Activity concentrations of ^{137}Cs in sediment samples are measured at the HCMR MERL (Marine Environmental Radioactivity Laboratory) using a HPGe detector (Ortec Coaxial n-type HPGe system) with a nominal relative efficiency of 50% and resolution of 1.85 keV at 1.33 MeV. A lead shield surrounded the detector in order to reduce the ambient gamma-ray background. Data quality is checked against the standard sample IAEA-414. The confidence interval of the reference values was 338.3–395.0 Bq/kg, while the measured (20 measurements) confidence interval was from 373.3 to 486.6 Bq/kg. Furthermore, the two methods (total alpha, gamma spectrometry) were applied on a reference sample (IAEA-385) and the results of the activity concentration of ^{210}Pb were in a very good agreement within their uncertainty bars (< 8%). Several studies have been carried out in Greek marine and freshwater environments. The active sedimentation rates (100-120 years) were calculated in cores collected in the Northern Evia Gulf and in Alkyonides Gulf. These gulfs are characterized by high seismicity and constitute two of the most active regions of Central Greece in terms of neotectonic deformation. Sediment accumulation rates were also studied in various estuary systems in Greece. Sediment accumulation appeared to be regulated by variations in the riverine discharge, shelf transport pathways and winnowing processes. Furthermore, the use of ^{210}Pb and ^{137}Cs was tested in the study of the radio-pollution history in sediments in the vicinity of the airport in the eastern part of Thessaloniki gulf. The ^{210}Pb is also used in sedimentation studies in deep marine areas where the higher isotope activities were measured in the surface sediments, whereas, the sedimentation rates were very low.

The use of radioactive tracers to measure the variability of photosynthetic and bacterial productivity in Aegean marine waters

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Abstract There are several methods for measuring bacterial and primary production in sea water. Both *in situ* (in the field) and *ex situ* (laboratory experiment) methods have been developed. This paper aim to present methods that are commonly used for measuring production of bacteria and photosynthetic organisms, by using radioactive tracers, as well some characteristics results from the Aegean marine waters. Plankton photosynthesis, responsible for about half of the primary production in the biosphere, is a fundamental process at the global and the ecosystem scale. At the global scale, phytoplankton primary production affects oxygen and CO_2 fluxes, constraining gas exchange with the atmosphere and thus the gaseous composition of the atmosphere. Furthermore, phytoplankton primary production is the main source of organic matter fueling marine food webs. The measurement of phytoplankton primary production is so a fundamental property of the ocean ecosystem, receiving considerable effort that has resulted in several million estimates available to-date. The theory behind using ^{14}C to measure productivity involves using a labeled tracer to quantify assimilated carbon. The ^{14}C-labeled method (Steeman Nielsen, 1952) consists of measuring the photosynthetic incorporation of ^{14}C labeled inorganic C, added as a $NaH^{14}CO_3$ solution, into particulate and total pools of organic carbon. The method is based on the assumption that biological uptake of ^{14}C-labelled DIC is proportional to the biological uptake of the more commonly found ^{12}C DIC. In order to determine uptake, one must know the concentration of DIC naturally occurring in the sample water, the amount of ^{14}C-DIC added, and the amount of ^{14}C retained in particulate matter (^{14}C-POC) at the end of an incubation experiment. A 5% metabolic discrimination factor may be applied to the data as well, since organisms preferentially take up lighter isotopes. Furthermore, as an approach to the measurement of prokaryotic carbon production, the incorporation rates of tritiated leucine are measured. Heterotrophic bacteria tend to incorporate it into their protein rather than metabolize it and resynthesize it "de novo". Thus, biomass production from protein production rates can be calculated, knowing the protein-to-carbon ratio, which is rather constant and using conversion factors, in order to transform activity (incorporation rates) to production rates. A lot of studies use the above methods for the determination of prokaryotic C and phytoplanktonic C production in the water column and the evaluation of its relationships with biological and physicochemical parameters. The existence, functioning and magnitude of microbial food webs have been intensively been studied over the last two decades. The term 'microbial loop' refers to the bacterial recovery through uptake and metabolism of DOM, lost in the pelagic trophic system through phytoplankton exudation or excretion from several organisms. Estimates of bacterial production establish the importance of the microbial loop and of microbial food webs initiated by bacterivory in marine ecosystems. In the oligotrophic Eastern Mediterranean where a large part of the fixed carbon is channeled through the microbial food web these studies can help to investigate bacterial growth processes in the sea, understand the role of the heterotrophic bacteria in the flow of energy within the planktonic food web and provide data for ecological model studies. Results highlight a trend of decreasing bacterial activity from the West to the East Mediterranean sea. Increase in temperature stimulates bacterial activity, which is sometimes strongly limited by the low amount of dissolved organic matter, whereas phosphorus and nitrogen limitation or colimitation may also occur. Authors often claim positive linear correlation between bacterial production and primary production which is a source of carbon for bacteria.

Thermal and fast neutron flux studies in a subcritical neutron assembly regarding to neutron absorption cross section estimation

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Abstract This project was conducted in order to experimentally study the thermal and fast neutron flux in the subcritical assembly of the Atomic and Nuclear Physics laboratory at the Physics Department of Aristotle University of Thessaloniki. The measurements took place in horizontal and vertical distances from the Am-Be neutron source, which was located in the center of the subcritical assembly. Inside the reactor, except from the neutron source there are also the fuel rods containing natural uranium. The remaining volume of the reactor is filled with light water, which works as a neutron moderator and also a reflector preventing the escape of neutrons. Therefore measurements were performed with and without the fuel rods of the reactor. The results derived applying Neutron Activation Analysis (NAA) from gamma spectroscopy, using an HPGe detector. Indium samples (^{115}In) were placed into the subcritical assembly for a specified time in order to activate the desired isotopes: (a) ^{116}In by capturing thermal neutrons: $^{115}\mathrm{In} + n \rightarrow {}^{116}\mathrm{In} + \gamma$ and (b) ^{115m}In through inelastic scattering of fast neutrons: $^{115}\mathrm{In} + n \rightarrow {}^{115m}\mathrm{In} + n' + \gamma$. Finally, according to the data determined the macroscopic as well as microscopic cross sections of thermal and fast neutrons absorption in water and natural uranium have been estimated following the exponential reduction of neutron flux vs. the distance of the irradiated indium foils.

Study of Stopping Power and Energy Deposition of Atmospheric Muons in the Spherical Proportional Counter (SPC): Simulation Using GEANT4 and Experimental Data

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Abstract Muons are negatively charged particles-much heavier than electrons-produced in the atmosphere as a result of the interaction of the incoming cosmic rays (basically protons) with the atmospheric nuclei. According to measurements, the kinetic energy of atmospheric muons at sea level for vertical fluxes, starts below 1 GeV and can exceed 10 TeV. These extremely penetrating particles are one of the main causes of background in detectors. The study of this background is essential especially in the case of the spherical proportional counter for the detection of neutrinos through coherent-scattering. The study of the muon background is focused in two physical quantities: the Stopping Power $< dE/dx >$ and the total energy deposition. In this paper, the results of stopping power $< dE/dx >$ as a function of muon's kinetic energy and the total energy deposition of atmospheric muons in the spherical proportional counter are presented. For the purpose of the study GEANT4 has been used together with experimental data. The simulation and the experimental data are in agreement.

Mapping of the secondary neutron dose received in 15 MeV medical linac environments

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Abstract A mapping of photo-neutrons dose in several positions over the treatment table of a medical linac has been taken place for a photon bean of 15 MeV. Neutron activation technique has been applied in order to obtain the neutron spectrum over a wide energy range in the intense and mixed γ-n field of a medical linac using thick foils due to low neutron fluence rates. The experimental results lead to useful conclusions regarding the fluctuations of the secondary neutron dose over the patient body and thus the estimation of the ambient dose equivalent received by the target-organ as well as the surrounding organs.

Actinides in coastal sands from Nisyros island and Northern Greece: A comparative investigation

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Abstract Coastal sand samples collected from the northern part of Nisyros volcanic island (Dodecanese, Greece) were investigated for first time for their potential in actinides (U, Th) and strategic metals and compared with parental source rocks and fresh hydrothermally deposited material from the island's caldera crater. Powder X-ray diffraction (PXRD) and the scanning electron microscopy (SEM-EDS) examination of the coastal sand showed different mineralogical composition and geochemical patterns compared the hydrothermally deposited material of the caldera crater. Weathering processes contributed to accumulation of heavy minerals, mainly ilmenite, and strategic metals (e.g. V and Nb). The rare-earth element (REE) and actinide concentration in the sand was found to be lower because of the absence of REE-rich minerals. The volcanic source rocks of the island were found to be especially enriched in large-ion lithophile elements (e.g. K, Rb, Cs, Sr, Ba) and depleted in high-field strength elements (e.g.Ti, Zr, Nb and Ta). The caldera material was enriched in volatile components, sulfur, chalcophile elements (Se, Bi, Hg, As, Pb) and Ba. Micro-XRF analyses of representative crystals showed that the high Nb content of the sands was associated with the Ti/Fe-rich phases (e.g. ilmenites). The Nisyros sand was also compared with relevant materials collected from locations near N. Greece granitoids. The geochemical composition of these sands showed enrichment in high-field strength elements, actinides and REE. This was especially obvious in the sands of Sithonia and Kavala (ΣREE+Y = 10810 mg/kg) region due to the fact that their source rocks were mainly granitoids with REE-rich accessory minerals such as monazite, allanite and zircon. The Th-content of Kavala beach sands was found to be elevated (ca. 1200 mg/kg) while their U-content lower (ca. 54 mg/kg). SEM-EDS measurements combined with μ-XRF in raw crystals from the sand showed that the REE and the actinides were mainly associated with allanites, apatites, zircons and monazites. Ti-oxides and titanites contributed to their elevated REE concentration. This work can act as a model study for sands of the whole Hellenic Volcanic Arc (HVA) and relevant volcanic areas in Mediterranean region.

Radiological Parameters Applied in Non-human Biota Dose Assessment Tools Calculated Using ERICA Tool and Site-specific Data

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Abstract The substantial complexity in ecosystem - radionuclide interactions is difficult to be represented in terms of radiological doses. Thus, the radiological dose assessment tools use typical exposure situations for generalized organisms and ecosystems, but the possibility for adaptation in the specific ecosystem features and organism parameters is provided, as well. In this study, site-specific data and actual radioactivity measurements of terrestrial organisms (grass and herbivore mammals) and abiotic components (soil) are provided. The measured data are used in combination to ERICA Assessment Tool for the calculation of the radiological parameters. The process of radionuclide's transfer within ecosystem components is represented using the Concentration Ratio (CR), while for the calculation of dose rates the Dose Conversion Coefficient (DCC) methodology is applied. Comparative assessments are performed between the generic and assessment-specific radiological parameters and between the respective resulted dose rates. Significant differences were revealed between the concentration ratios calculated in this study and the values reported in the literature for cesium and thorium, but there are natural explanations to them. On the other hand, the values calculated for radium were in very good agreement with the literature. The DCCs exhibited some small differences between the reference and the site-specific organisms due to mass differences. As it was expected, these differences were transferred to the internal and external dose rates, but with insignificant impact. Furthermore, it was observed that the differences for internal and external dose rates were not reflected on the total dose rate which is the quantity used in radiological impact assessment studies. The results of the current work could serve as a basis for further study of the behaviour of the radiological parameters in similar environments.

Thin film profile measurements using RBS

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Abstract Thin film profile measurements were performed using the Heavy Ion Rutherford Backscattering Spectroscopy technique. The experiments were conducted at the Tandem accelerator laboratory of NCSR "Demokritos", by utilizing a 10 MeV ^{12}C beam from the 5.5 MV terminal voltage accelerator of the laboratory. A number of samples of Ta, Hf and Ti oxides and nitrides were measured. The samples were manufactured at the Electronic Nanomaterials and Devices laboratory of the National Technical University of Athens, using the RF Magnetron Sputtering technique. The results of the characterization of the samples and their performance are presented.

Photodisintegration average cross sections of Dysprosium p-nuclei near (γ, n) reaction threshold

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Abstract First measured cross-section data on (γ, n) reaction of Dysprosium proton rich nuclei ^{156}Dy and ^{158}Dy was experimentally determined via activation methods using bremsstrahlung photons beam delivered by an electron medical accelerator. An integrated cross-section of 144 ± 44 mb is calculated for the ^{156}Dy (γ, n) reaction at the energy interval 9.4 - 14 MeV while for the ^{158}Dy (γ, n) reaction at the energy interval 9.1 - 14 MeV is estimated as 168 ± 42 mb. Moreover, theoretical calculations have been performed for all Dy isotopes employing TALYS code. The effect of the nuclear-physics input parameters (γ-ray strength function, nuclear level densities) on the cross section calculations has been studied to successfully reproduce the experimental data. The effective cross section estimated using the TALYS code range between 115 and 206 mb for ^{156}Dy (γ, n) and between 124 and 206 mb for ^{158}Dy (γ, n) reaction depending on the γ-ray strength function used.

Developments in 2D and 3D XRF analysis from the Micro to Macro scale imaging of Cultural Heritage artefacts

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Abstract X ray fluorescence analysis has been established as a valuable tool in the scientific investigation of archaeological/historical objects and artworks since it can provide in-situ, non-invasive multi-elemental analysis with parts per million (ppm) analytical sensitivity for certain elements. The development of high performance polycapillary lenses as X-ray focusing devices paved the way for 2D elemental imaging capabilities with spatial resolution in the range of few tens of μm, thus allowing the examination of fine details of archaeological artefacts and artworks. The introduction of a second polycapillary lens in front of the X-ray detector creates from the intersection of the two X-ray lenses foci a confocal micro-volume. By shifting the probing micro-volume through the analyzed sample, depth resolved XRF measurements can be acquired, whereas in conjunction with the 2D scanning X-ray microprobe possibilities, 3D element specific imaging can be achieved [1]. Instrumental and hardware developments have significantly upgraded the in-situ XRF imaging capabilities, from micro-scale regions (~mm^3) to macro-scale (~cm^3). Novel mobile MAXRF scanners [2] offer nowadays a real-time elemental imaging of large dimensions artefacts/artworks. This is achieved by means of careful optimization of the hardware components and experimental parameters taking advantage of available in the market large area silicon drift detectors and ultra-fast digital signal processors. A Macro-Analysis XRF (MA-XRF) scanner can operate on the fly with a maximum speed of 100 mm/sec, counting statistics in the range of about 0.7-0.8 Mcps, acquisition time in the msec range analyzing an area of 110 x 70 cm^2 in only 4 h with 500 μm lateral resolution [2]. These capabilities offer a breakthrough in the way that XRF analysis can be utilized in the field of Cultural Heritage. Instead of spot by spot, or single micro-area measurements, the holistic 2D/3D X-ray images offer an integrated visual view how ancient/historical artefacts/artworks were made. Moreover, in many cases MA-XRF imaging can bring to light iconographic elements that were thought to be lost forever. Characteristic examples from recent investigations will be presented and discussed.

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Radiological studies of zeolites application in the environment

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Abstract The present work is focused to natural radioactivity levels of zeolites in order to define their limits of usage in the environment considering dose consequences to the public. The natural radionuclides have been measured using gamma-ray spectrometry alongside with the radon emanation factor variations due to granulometric effect. The environmental applications of zeolites as cultivation soil improvements, dietary supplements and building materials has been considered regarding to evaluate the limits for internal and external radiation exposure rates.

Natural radioactivity levels in wheat, farm soils and phosphate fertilizers

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Abstract Fertilizers, agricultural soil and wheat samples were collected, air dried and then they hermetically sealed in Marinelli beakers. The samples were stored one month, thus secular equilibrium of ^{226}Ra and its products was obtained. Radioactivity concentrations of naturally occurring radionuclides, ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K of these samples were determined by gamma spectrometry using HPGe. Materials for sealing Marinelli beakers have been investigated in order to prevent radon to escape from the measured samples. Specific activity levels due to ^{226}Ra were measured using HPGe, before and after the sealing of beakers. The measurements of this study can provide data for environmental radioactivity in the region of Greece regarding to assess the exposure dose rate of population due to the presence of radioactive materials. In fertilizers ^{238}U concentrations ranged from 44 to 710 Bq/kg, ^{226}Ra concentrations ranged from 7 to 529 Bq/kg, ^{232}Th concentrations ranged from 21 to 95 Bq/kg, ^{40}K concentrations ranged from 38 to 4483 Bq/kg. In fertilized soil samples ^{226}Ra concentrations ranged from 8 to 68 Bq/kg, ^{232}Th concentrations ranged from 8 to 79 Bq/kg while ^{40}K concentrations ranged from 185 to 868 Bq/kg. In wheat samples only ^{40}K has been found and its concentrations ranged from 109 to 200 Bq/kg. Total absorbed dose rates of the natural radionuclides were calculated and founded to have a mean value in soils 52.61 nGyh^{-1} and 202.56 nGy h^{-1} due to fertilizers.

A High Performance DAQ System for a Free Hand Small-Field γ-Camera

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Abstract A high performance software for a real time data acquisition system, running on the LabVIEW environment, has been developed in our Lab. LabVIEW is an instrumentation-oriented graphical program, which integrates with our existing hardware, consisting of a high resolution portable γ-Camera based on a cylindrical Position Sensitive Photo-Multiplier Tube (HAMAMATSU R2486), a fast ADC PCI card and Nintendo's Wii Remote. The outer goal for the free hand γ-Camera prototype is to be engaged in clinical application during surgical procedures. Consequently among the basic requirements during the data-taking procedure is a high counting rate and the absence of any distorting motion. The newly developed software takes full advantage of the 20 MHz cards sampling rate, allows the recording of the four input signals simultaneously and performs an on line position and energy reconstruction. To overcome any stability problems a real time and on line position correction technique on an event-by-event basis is included. This is achieved by storing acceleration data along the cameras three axes plus the IR data given by Wii Remotes IR sensor. The softwares inner architecture straightforwardly allows a number of additions and modifications in the existing code. It has a user- friendly graphical interface, since there is no demand of any prior programming skills, due to simulated controls and indicators.

PhoSim: A Software Simulation Package Designed for Macroscopic and Microscopic Studies in the Time-Resolved Optical Tomography

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Abstract **PhoSim** is an optical ray tracing Monte-Carlo simulator capable of reproducing the physical processes taking place in a tissue environment when illuminated by Near-Infrared radiation. From a macroscopic point of view this can be accomplished by the proper manipulation of the Henyey-Greenstein phase parameter g, which represents a simple and analytical solution for the fast generation of a random scattering angle photon distribution. Microscopically, the program can simulate certain biological structures by placing a proper density of subcellular organelles inside the volume of interest, proportional to the wavelength of the radiation used at the study (~750-1000 nm). The new version of this software package is able to create different type of phantoms in multilayer environments and it is also equipped with a detailed Fate and Time of Flight information of each traveling photon. **PhoSim** is a simple and useful tool for Time-Resolved Optical Tomographic studies; its basic functions and capabilities with optical tomographic examples are presented in this work.

CSIM – A new code for the simulation of channeling EBS/RBS spectra

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Abstract This work represents an attempt to solve a long-standing problem in ion beam analysis (IBA), namely, the successful quantification of channeling EBS/RBS spectra, for which a new phenomenological simulation code – CSIM – has been developed. Successfully quantified c-EBS/RBS spectra open new possibilities for the determination of low concentration profiles of light elements implanted or generally present as interstitial impurities in heavier crystalline matrices, whose yield in standard EBS/RBS spectra overlaps with the matrix-induced background. CSIM is a computer code written in C++, which assumes that the phenomenological channeling process can be described by only three extra parameters. Two parameters, namely the dechanneling rate and range, are used to describe the Gompertz-type sigmoidal dechanneling process, since already dechanneled ions, which are subsequently backscattered, are the main yield contributors in c-EBS/RBS spectra. The third parameter describes the energy loss in the channeling mode, and, more specifically, the channeling to random mode energy loss ratio. These three parameters can be either manually set by the user or obtained via the χ^2 minimization MINUIT routine from experimental data. CSIM has been successfully tested in reproducing 1-2 MeV proton c-EBS spectra of virgin crystals, like [110] Si and [100] diamond. Moreover, CSIM has been successfully used in obtaining amorphization profiles in the case of 4 4 MeV C^{3+} ions implanted in diamond in the channeling orientation A user-friendly visual interface is currently being developed, and thus, CSIM will soon be available to the scientific community for downloading, evaluation and testing.

Neutron Radiography using isotopic neutron sources: Preliminary results

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Abstract Neutron Radiography (NR) is a non-destructive imaging technique with high sensitivity to light elements, which makes it of great use when identification of light materials inside solid samples is required. In the present work we have examined the feasibility to perform neutron radiography using an (a,n)-type neutron source in conjunction with an Imaging Plate for analysis of large scintillation detectors and electronic components. A PGNAA system using Pu/Be neutron source was modified for the experiments. The results were compared with high-resolution X-ray computed tomography images of the detector components. The results of the study suggest that for successful neutron imaging a well moderated and collimated neutron beam is required. Whereas CT provides fine resolution for determining outer crystal dimensions, NR can provide information on possible mechanical damage, humidity concentration etc. Further exploitation of the results is expected to improve the application of NR when using an isotopic neutron source (Pu/Be).

Detailed efficiency simulations of the GEROS spectrometer using MCNP5

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Abstract A gamma spectrometer developed around a decommissioned p-type, co-axial HPGe detector has been recently returned to operational mode at the University of Athens with main aim to be used in environmental radioactivity studies. GEROS (Germanium for Environmental RadiOactivity Studies) was fully characterized obtaining information on its linear response, efficiency and energy resolution based on CT and gamma tomography. Due to prolonged inactivity, the HPGe detector was expected to have a rather significant dead layer developed, a factor known to affect the detection efficiency, especially for low-energy photons. For this purpose, we have undertaken systematic Monte Carlo simulations to determine the actual thickness of the dead layer, which could not be determined accurately from the previous techniques. In the present work, the efficiency calibration of the detector has been performed in the energy range 100-1500 keV using the Monte Carlo code MCNP5. The results from previous studies were combined to provide initial input to subsequent MCNP5 simulations. The simulations resulted in a dead-layer thickness value, which is smaller than the ones estimated earlier. In addition, it was found that the only parameter affecting the crystal's active volume is the existing borehole. The importance of the dimensions of the borehole was tested further, by varying its diameter. The final conclusion on the detector's geometry and properties will be additionally discussed in terms of our earlier experimental results.

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Comparison of two sample preparation techniques for XRF analysis of fly ash samples

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Abstract Aim of this work is the comparison of the two techniques used at the Nuclear Engineering Department of NTUA (NED-NTUA) for X-Ray Fluorescence (XRF) analysis sample preparation. With the first technique the sample is pressed in a pellet form while with the second technique (fusion) the sample is dissolved into a solvent to produce a solid glass disk. For the sample preparation in pellet form, a 20t hydraulic press is used to compress the material under analysis – mixed with a binder additive – inside 40mm diameter aluminium cups. For the fusion sample preparation technique the K1 Prime Fluxer is used for the fusion process. In this case the material to be analysed is dissolved in high temperature into lithium borate solution. The solution is poured into the mould (40mm diameter) and after cooling in room temperature the final sample disk is ready to be analysed. The samples produced by each technique have almost the same volume but differ in many ways. The pressed pellet sample contains approximately 80-90% of the material to be analysed (fly ash). The fusion disk contains only 5-10% of the material to be analysed (fly ash), the rest being lithium borate salts. As a result, in this technique the concentrations of the major components of the prepared sample are known, allowing for a better calibration of the technique. The X-ray Fluorescence analysis of both types of fly ash samples was performed using the NED-NTUA Energy Dispersive XRF facility for the determination of a series of elements. The main components of the facility are: an X-ray tube with Mo target, (50kV, 1mA) and a Super-SiLi X-ray detector. The X-ray spectra are collected by a pocket MCA (AMPTEK) connected to a PC. The collected spectra were analysed by bAXIL software and standard based Fundamental Parameter method using high purity metal oxides and salts. An extensive investigation on the effect of various parameters, such as mass the percentage of lithium salts and the fusion parameters (temperature, duration etc) was carried out to reach the best possible fusion sample for fly ash. For the comparison of the two sample preparation techniques in terms of accuracy, precision and detection limits, the NIST Standard Reference Material ‘coal fly ash 1633b’ was used. For this purpose the spectra of the two types of samples (pellet and fusion disk) in different operational conditions were collected. Two different scenarios were examined: (a) 15kV, aluminum filters and (b) 35kV molybdenum filters. From the results obtained it may be concluded that both preparation techniques provide acceptable results for a series of elements in fly ash samples, namely: Ca, Ti, Cr, Fe, Ni, Cu, Zn, As, Rb, Sr. As The fusion technique which requires small amount of material is more appropriate for major elements, while the pressed pellet technique is more appropriate for trace elements.

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Potentialities and perspectives of proton induced quasi-monochromatic X-rays in fundamental studies and analytical applications

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Abstract The use of ion induced quasi monochromatic X-rays has been envisaged since 1983 [1] in various analytical applications, including the selective XRF analysis of bulk samples but also for elemental imaging purposes through the formation of X-ray microbeams. The ideas presented in this pioneer work were motivated by the benefits offered by the various physical processes that govern the energetic ion-induced emission of X-rays by solid targets: the high inner-shell ionization cross sections and generally the very low emission of bremsstrahlung radiation following the ion-impact (two-three orders of magnitude lower compared to electron-impact). Various groups have mostly employed proton induced quasi monochromatic X-rays for improving detection limits of trace elements [2]. Proton induced X-ray microbeams have been generated utilizing different set-up configurations and X-ray focusing optics such as polycapillary X-ray half lens [3] and Fresnel zone plate [4] to achieve selective elemental imaging capabilities [3] and consistent dose delivery during irradiation of a single cell layer [4], respectively. The quasi monochromatic X-ray beams generated at the Tandem 5.5 MV accelerator of INPP, NCSR "Demokritos" have been proven by Sokaras et al. [5, 6] as a reliable X-ray source to be used in fundamental X-ray studies. In more specific, the measurement of absolute Resonant Raman Scattering cross sections [5] and the study of L-shell cascade X-ray emission [6] have been carried out generating results in very good agreement with those obtained with synchrotron radiation. These potentialities, but also additional perspectives which can be triggered by optimizing features of the set-up configuration and experimental parameters are presented and discussed.

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Nuclear analytical techniques for the chemical characterization of aerosol samples

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Abstract Environmental pollution and especially air pollution, are receveing increasing attention in the last decades. Aerosols or airborne particulate matter (APM or PM) are one of the most important air pollutants. PM can be comprised of a wide variety of chemical species. Potentially a more effective approach would be to consider the airborne PM as a mixture of mass contributions by various source classes [1]. The identification of those sources can be performed with the use of various receptor models such as PMF (Positive Matrix Factorization) and CMB (Chemical Mass Balance). In order to apply effectively and comprehensively receptor models, a large number of samples and chemical species per sample, must be gathered for a given receptor over time. Species of similar variability are grouped together by receptor models, in a minimum number of factors that explain the variability of the data set. It is assumed that each factor is associated with a source or source type. The nuclear analytical techniques were Particle induced X-ray emission (PIXE) and X-ray florescence spectroscopy (XRF). PIXE has many advantages for elemental analysis of particulate matter samples: it provides rapid multielemental analysis, capable to detect up to a large number of elements, including important anthropogenic elements (S, V, Ni, Cu, Zn, As and Pb) and all the crustal elements (Al, Si, K, Ca, Ti, Mn and Fe). Additionally, a commercially available XRF system was utilized (Epsilon 5 by PANalytical, the Netherlands), for the application of the XRF technique. This system offers a combination of secondary target and three-dimensional polarizing optical geometry, that drastically reduces the scattered X-ray spectrum from the tube and hence it causes a significant decrease of the detection limits. Both techniques were effectively utilized for the creation of an appropriate elemental composition dataset which was subsequently used for the application of source apportionment techniques. PMF results from datasets created by the application of PIXE and XRF techniques from two sampling campaigns in Patras (elemental composition determination by XRF) and Megalopolis (elemental composition determination by PIXE) will be presented and the differences in the profiles of the common sources identified in each area will be discussed.

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Radon Monitoring as Part of Multidisciplinary Study of Pre-Earthquake Anomalies in the Western Hellenic Trench*

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Abstract Anomalous variations of radon concentration in the soil gas have been attributed to seismic activity in many cases worldwide, evidencing radon as a particularly promising middle-term pre-earthquake precursor [1]. However the shortage of long term systematic experimental data and the lack of a sound theory that can accurately explain and justify the phenomenon, have hider the seismological community from establishing radon as a tool for forecasting earthquakes [2]. Motivated by this, an integrated observational prototype of multiparameter network approach has been recently developed, aimed at monitoring and thorough studing of pre-earthquake processes at the high seismicity area of the Western Hellenic Arc [3]. Part of the integrated study is a radon measurement network for continuous real-time monitoring of radon gas accumulation in the ground. The network consists of three gamma ray detectors and the radon activity is estimated via its progenies (^{214}Bi and ^{214}Pb) based on automated full spectrum analysis technique. Local meteorological parameters for atmospheric corrections are also continuously monitored. Here, we present installation details, data manipulation, analysis techniques and first results after one year of the radon network operation. Comparative study of seismological data with precursor measurements of radon, microseismicity and satellite thermal radiation are also discussed.

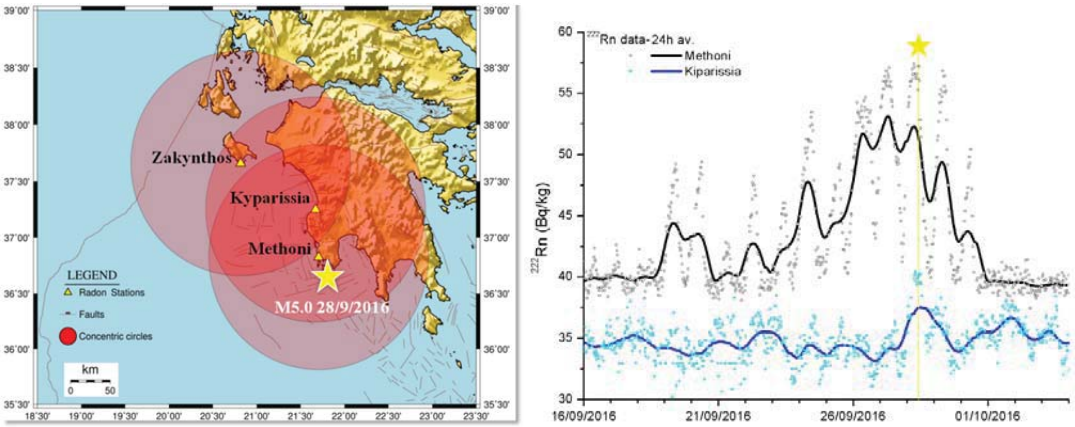

Fig.1. The location of the 3 radon stations with the estimated coverage area (~100 km) and the radon anomalies recorded before the M5.0 earthquake of 28 September 2016, 18 km N Methoni.

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